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ON RADIATIVE HEAT TRANSPORT IN THE ATMOSPHERE OF VENUS UNDER THE CLOUDS

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In order to explain the high surface temperature of Venus due to the greenhouse effect, the radiative heat transport in the convective lower atmosphere of the planet was considered in [1] with regard to the parameters of the Venus atmosphere, measured by the automatic stations "Venera-4" [2, 3]. /311*

The flights of the automatic interplanetary stations (AIS) "Venera-5" and "Venera-6" have given more complete information about the parameters of the atmosphere of Venus. According to the measurements they made, the pressure and temperature on the surface of Venus are between $\sim$ 65-150 atm and $\sim$ 710-830° K, respectively, [4]. It is of interest to evaluate the effectiveness of the "greenhouse" effect on Venus with regard to data obtained in "Venera-5" and "Venera-6". Results are accordingly given below of calculating the radiative heat flux in the atmosphere of the planet beneath the clouds and estimates of its surface temperature, using the data given in [4].

*Numbers in the margin indicate the pagination in the original foreign text.

Radiative heat flux F was found according to the method outlined in [1]. Surface pressure and temperature were taken as 90 atm and 750° K, respectively, i.e., close to the average values $P_{surface}$ and $T_{surface}$ obtained from the measurements of "Venera-5" and "Venera-6". Relative contents of CO_2 and H_2O in the atmosphere were assumed to be f_{CO_2} = 95% and f_{H_2O} = 0.1-0.3%, respectively [2, 4, 5], and the adiabatic temperature gradient was β = 8.9° K·km^{-1}. Test calculations showed that possible change of β within the atmosphere by 1° K·km^{-1}, caused by the temperature dependence of the heat capacity of carbon dioxide, does not significantly affect the heat flux values. /312

Figure 1 gives the total heat flux F_1 and F_2, resulting from radiative transport, in the "transparent windows" 825-1325, 2025-2175 and 2525-3425 cm^{-1} (curves 1-3) and in the "windows" 3975-5125 and 5525-7025 cm^{-1} (curves 1'-3'), respectively. Complete radiative flux is defined as the sum of fluxes at all five "transparent windows". Along the vertical axis in Figure 1 we see the relation of value $F_{1,2}$ to the energy flux escaping into outer space from the upper edge of the Venus cloud cover, i.e., $Q_{1,2} = F_{1,2}\ (z)/\sigma \cdot T_e^4$, where σ is the Stefan-Boltzmann constant, and T_e is the effective radiation temperature of the planet in the infrared range. Altitude z and the temperature corresponding to it of the atmosphere are plotted along the horizontal axis. From the curves in Figure 1 it is evident that at all levels in the atmosphere a large part of the radiative heat flux is composed of the flux transferred to "windows" with centers close to 1.7 and 2.2 μm. The value of F changes little with altitude, and at all levels does not exceed 0.3 of the flux escaping from the outer edges of the clouds. Thus, in the atmosphere of Venus beneath the clouds, energy transport is basically convective, and temperature distribution with altitude is close to adiabatic. This, of course, does not apply to the atmosphere layer lying directly next to the surface in which convective heat exchange is inhibited, and heat transport occurs by means of turbulent and radiative heat exchange.

Figure 2 gives the temperature dependence of radiative heat flux on the surface level, which determines heat loss by the surface due to radiation.

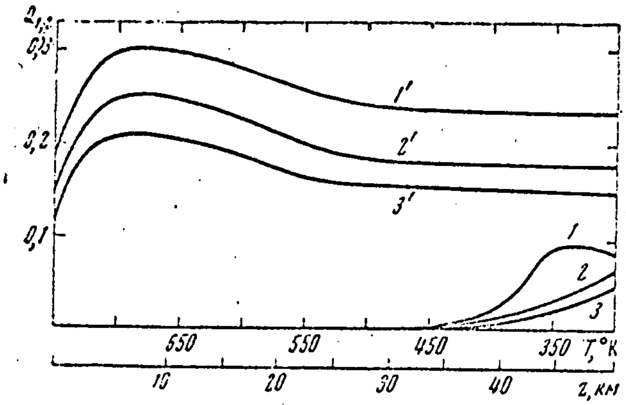

Figure 1. Radiative heat flux in individual sections of the infrared range of the spectrum ($T_{surface}$ = = 750° K):
1 - Q_1 (f_{H_2O} = 0.1%), 1' - Q_2 (f_{H_2O} = = 0.1%), 2 - Q_1 (f_{H_2O} = 0.2%), 2' - Q_2 (f_{H_2O} = 0.2%), 3 - Q_1 (f_{H_2O} = = 0.3%), 3' - Q_2 (f_{H_2O} = 0.3%).

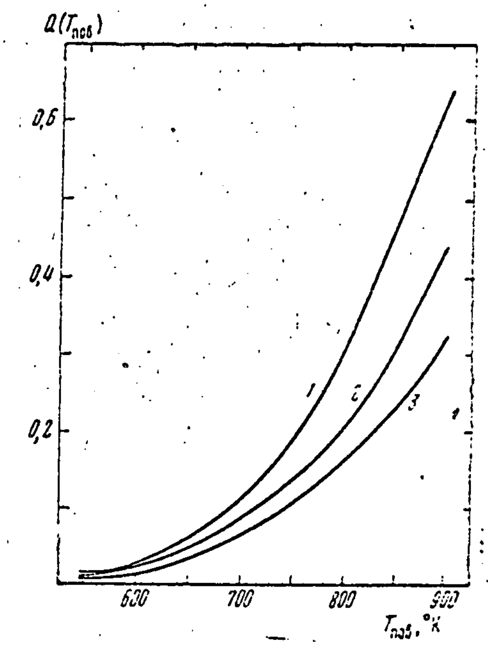

Figure 2. Radiative heat flux at surface level ($T_{surface}$ = 750° K: 1 - f_{H_2O} = 0.1%, 2 - f_{H_2O} = 0.2%, 3 - f_{H_2O} = 0.3.

This value is one of the heat balance components of the planet's surface. At $T_{surface}$ = 550 - 850° K, we have $Q(T_{surface}) = F(T_{surface})/\sigma \cdot T_e^4 \lesssim 0.5$. Consequently, turbulent heat transport plays an essential role in cooling the surface. The solution of the heat balance equation for the surface of Venus, carried out analogously to [1], shows that at $P_{surface}$ = 90 atm, the greenhouse effect heats up the surface to 700-850° K, which corresponds to data from the measurements made by "Venera-5" and "Venera-6". Daily mean heat losses from the surface, due to turbulent transport, should constitute 50-90% of the incoming solar radiation.

The results given above thus show that the mechanism of radiative heat transport on Venus does not provide an escape mechanism into interplanetary space for the energy received by the planet from the Sun. This, first of all, leads to a high surface temperature, and secondly, indicates that heat transport in the atmosphere of Venus beneath the clouds is also due to convective and turbulent mechanisms. /313

REFERENCES

1. Strelkov, G.M. and N.F. Kukharskaya. Kosmicheskiye issledovaniya, Vol. 7, No. 2, 1969, p. 247.

2. Vinogradov, A.P., Yu.A. Surkov, K.P. Florenskiy and B.M. Andreychikov. Doklady AN SSSR, Vol. 179, No. 1, 1968, p. 37.

3. Avduyevskiy, V.S., N.F. Borodin, V.V. Kuznetsov, A.I. Lifshits, M.Ya. Marov, V.V. Mikhnevich and M.K. Rozhdestvenskiy. Doklady AN SSSR, Vol. 179, No. 2, 1968, p. 310.

4. Avduyevsky, V.S., M.Ya. Marov and M.K. Rozhdestvenskiy. Kosmicheskiye issledovaniya, Vol. 8, No. 6, 1970, p. 871.

5. Vinogradov, A.P., Yu.A. Surkov and B.M. Andreychikov. Doklady AN SSSR, Vol. 190, No. 3, 1970, p. 552.

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